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(54) Cold rolling method of strip.

(57) A cold rolling method of strip(1) is provided wherein the brushing roll (7), (8) are contacted to both the work rolls(5) and the back up rolls (6) of the temper mill, removing the foreign objects from the surface of the rolls of the mill and the duct(9) adjacent to the brushing rolls transport the foreign objects out of the mill system. The sucking speed of the duct is at least 5 m/sec., more preferably 8 m/sec. The length of the bristle is from 15 to 60mm, the diameter thereof being from 0.15mm to 1.0mm, and the material thereof being selected from a group of nylon, propyrene, and the mixture thereof. The density of the bristle with respect to the peripheral surface area of the brushing rolls for the work roll is from 55 to 85 % by area. Abrasive grains with the grain size of #300 to #1200 are incorporated in the brush of said brushing roll which enhance the brushing ability.

The material of the abrasive grain is one or more selected from a group of alumina, titania, and silicate, and volume percentage of the grain with respect to volume of brush is from 5 to 30 % in volume.

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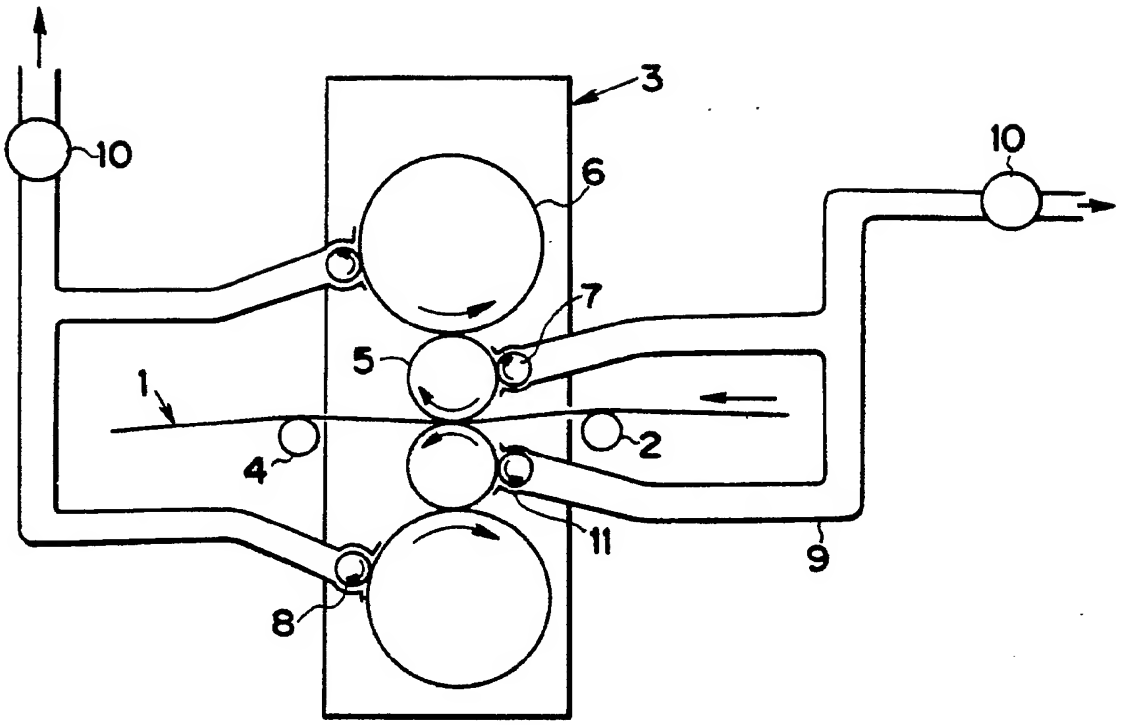
FIG. 1



COLD ROLLING METHOD OF STRIP

This invention relates to the field of the cold rolling of strip, and particularly to the field of the cold rolling of steel strip by temper mills.

When metal strips are rolled by temper mills, the cleaning of the surface of the rolls is required to maintain the surface quality of the strip products and to avoid the occurence of defects associated with the rolling. One of the cleaning methods is the constant removal of the foreign objects on the surface of the rolls by various means of brushing.

Japanese Patent Publication laid open No. 57-75212 discloses a method wherein brushing rolls are used for the removal of the foreign objects from the surface of the work rolls, and exhausting means are used for the transportation of the objects out of the rolling system. However, in the disclosed invention, the removal and the transportation is limited to the foreign objects on the surface of the work rolls. Accordingly, the complete removal of the objects is not attained due to the fact wherein the foreign objects on the surface of the back up rolls may contaminate the surface of the strip. To produce the strip with a matte surface, the surface of the work rolls has comparatively large roughness of surface, and the hardness of the surface of the back up rolls is lower than that of the work roll, which causes the generation of abrasive powders from the contact of the work roll and back up roll. The contact pressure between the work roll and back up roll is higher than that between the work roll and the strip, which causes the generation of the abrasive powders. Moreover,when the mill is driven by work roll, or back up roll of top side or bottom side, the contact surface of the rolls slips, which causes the generation of the abrasive powders. These facts necessitates the constant removal of the foreign objects on the surface of the work roll and the back up roll to prevent the contamination and/or surface defects of the strip.

The coventional method has the problem wherein the brushing ability or the suction speed in exhausting means worsened, and exhausting ducts may contact with the brushing rolls when the diameter of the brushed roll or the diameter of brushing roll are changed. Another problem in the conventional method is a scratch mark on the surface of the rolls, which is caused by the bristle of the brushing rolls unless the rolls of the mill stops the rotational movement synchronously with those of the brushing rolls.Another problem is the positioning of the brushing rolls when the rolls of the mill are changed and the brushing device including exhaust duct moves forward or backward, wherein a consideration is not given to the positioning of the brushing rolls.

Japanese Utility Model Publication laid open No. 54-101074 discloses a method wherein air blowing holes are attached to the brushing roll to prevent the generation of heat by the friction between the brushing roll and the brushed roll. However the density of the bristle is unevenly distributed, which causes a brushing pattern on the surface of the rolls of the mill, which is printed on the strip surface as unevenly distributed roughness.

Japanese Patent Publication laid open No. 57-75212 discloses a method wherein abrasive grain is incorporated in the brush of the brushing roll to assist in removing of the foreign objects and the rigidity of the bristle is enhanced.

However these measures cause the occurence of defects on the surface of the rolls of the mill.

It is an object of the present invention to provide a cold rolling method of strip.

It is an object of the present invention to provide a cold rolling method of strip, wherein the foreign objects on the surface of the rolls are effectively removed, and carried away from the mills.

According to the invention a cold rolling method of strip comprising step of contacting a plurarity of brush rolls with the rolls of the mill with the directions of the rotation thereof adverse to or the same with those of said back up rolls or work rolls and back up rolls,and step of sucking the air into ducts in the neighbourhood of said brush rolls.

The speed of the flow of said sucking is at least 5 m/sec, and more preferably 8 m/sec. The ducts and said brushing rolls are moved, independently or in unison, by access and recess mechanisms in view of the relative position thereof to the rolls of the mill, wherein the brushing pressure of the brushing rolls on the rolls of the mill and the rate of flow of said sucking is regulated, and the brushing rolls are recessed in case of the mill shut down, or the recess and access of the brushing rolls are excecuted in case of the change of the rolls of the mill. The material of the bristle of brushing rolls is selected from a group of nylon, propyrene, and the mixture thereof. The diameter of the bristle of said brushing rolls for the work rolls is from 0.2 mm to 0.8mm, for the rolls of the mill and the length of the bristle is from 15 to 60 mm.

The density of the bristle with respect to the peripheral surface area of the brushing rolls for the work rolls is from 55 to 85 % by area. Abrasive grains with the grain size of from #300 to #1200 are incorporated in the brush of the brushing roll. The volume percentage of the abrasive grain with respect to the volume of

brush is from 5 to 30 % in volume. The abrasive grain wherein the material is one or more selected from a group of alumina, titania, and silicate.

Figure 1 is a schematic side view of the apparatus in use of an embodiment of the present invention;

Figure 2 is a detailed schematic perspective illustration of the duct 9 in the neighbourhood of the rolls of the mill;

Figure 3 is a schematic illusration of the relative position of the work roll, the hood, and the brushing roll;

Figure 4 is a schematic side view of a mechanism of moving the duct;

Figures 5 and 6 are flow charts which automatically change the position of the brushing rolls and the opening of the duct, in mill operation, roll changing, and mill stop;

Figure 7 is a schematic perspective illustration showing the assembly of the brushing roll;

Figure 8 is the enlarged view of the structure of the brushing roll shown in Figure 7;

Figure 9 is a graph showing the relationship between the suction speed and the dust recovery ratio;

Figures 10 and 11 are graphs showing the relationship between the diameter of the bristle and the number or the volume of the iron particle per unit area of the surface of the roll of the mill; and

Figure 12 is a graph showing the relationship between the suction speed and the quantity of dust in the air at the back up roll.

In temper rolling of the strip, the finished strip is a final product.

Therefore, utmost care should be taken for the contamination or the defect generation of the strip surface. To evade above mentioned problem, first of all, the complete removal of the foreign objects on the surface of the back up roll and more preferrably work roll and back up roll of the mill by at least one brushing roll which contact at least one roll of the mill and rotate in the same or more preferrably reverse direction of the rolls of the mill with a plurarity of exhaust ducts attached close to the brushing rolls. Thus the foreign objects are removed from the surface of the rolls of the mill, and carried away out of the temper mill through the exhaust ducts.

In this removal apparatus, the distance between the brushing roll and the rolls of the mill, and the distance between the duct and the rolls of the mill should be changed by a moving mechanism which moves the duct and/or the brushing rolls foreward and backward. The purposes of the movements are the adjustment of the contact pressure of the brushing rolls on the rolls of the mills, the suction force of the ducts, and the positioning of the brushing rolls and the ducts in case of the change of the rolls of the mill. The suction speed of the air at between the ducts and the rolls of the mill should be at least 5 m/sec.,more preferrably 8m/sec., to carry the removed foreign objects out of the mill.

Concerning the bristle of the brushing roll, the material should be nylon, polypropyrene or the mixture thereof, the diameter thereof is 0.15 to 1.0 mm, more preferrably 0.2 to 0.8 mm , the length thereof is 15 to 60mm, the density thereof is 55 to 85 % by area percentage of the surface of the polishing roll. To promote the efficiency of the brushing, abrasive grains of which grain size is #300 to #1200, of which material is one or more selected from alumina, titania, and silicate, of which volume ratio by the volume of the brush is 5 to 30 %, is incorporated in the brush. The reason of the specification of the various range explained above is as follows.

1. The reason of attaching the brushing roll on the back up roll and more preferrably on the work roll and the back up roll is that the attachment of the brushing roll on the work roll is not enough to remove the foreign objects on the surface of the roll. The reason of the direction of the rotation of the polishing roll being adverse to that of the roll of the mill is that the foreign objects on the surface of the roll of the mill may not be completely removed, by rotating the polishing roll in the same rotational direction of the roll of the mill. However the direction of the rotation may be the same with that of the roll of the mill, according to the brushing condition.

2. When the material of the bristle is hard such as metal, the bristle causes a scratch mark on the surface of the roll of the mill, and the brushing ability is considerably lowered by the bending of th tip of the bristle. When the material of the bristle is soft, no polishing effect is expected.
Accordingly, the materials of nylon, polypropyrene, or the mixture thereof are selected.

3. When the diameter of the bristle is below 0.15mm, no brushing effect is expected. When the diameter is above 1.0 mm, the roll of the mill is easy to wear by the excessive brushing effect. Accordingly, the diameter of the bristle is determined to be 0.15 to 1.0mm, more preferrably 0.2 to 0.8 mm.

4. When the length of the bristle is below 15mm, the bent bristle can not recover to be straight, which causes the reduction of the brushing ability. When the length of the bristle is above 60mm, the rigidity of the bristle is reduced, which causes the reduction of the brushing ability. Accordingly, the length of the bristle is determined to be 15 to 60 mm.

5. When the density of the bristle is below 55 % by area percentage of the surface of the brushing

roll, the surface of the roll of the mill is unevenly brushed, which causes a brushing pattern on the surface. When the density of the bristle is above 80 % by area percentage of the surface of the brushing roll, the bristle dose not recover to be straight after the brushing.

Accordingly, the density of the bristle is determined to be 55 to 80% by area percentage of the surface of the brushing roll.

6. The incorporation of the abrasive grain to the brushing roll is an effective way to enhance the brushing ability. When the grain size is below #1200, the brushing ability is not sufficient. When the grain size is above #300, the brushing ability is excessive, which causes a scratch mark on the surface of the roll of the mill. Accordingly, the grain size of the abrasive grain is determined to be #300 to #1200, more preferably, #1000 to #1200 for work roll and #500 to #1000 to the back up roll.

7. The material of the abrasive grain is one or more selected from alumina, titania, silicate, and their compounds in consideration of their polishing effect.

8. When the volume ratio of the abrasive grain by the volume of the brush is below 5%, the brushing ability is not sufficient. When the volume ratio of the abrasive grain by the volume of the brush is above 30%, the strength of the bristle is worsened and the brushing ability is saturated. Accordingly, the volume ratio by the volume of the brush is determined to be 5 to 30%.

9. The suction speed of the air at between the ducts and the rolls of the mill should be at least 5 m/sec., more preferrably at least 8 m/sec., to carry the removed foreign objects out of the mill.

10. The distance between the duct and the rolls of the mill and the opening degree of the duct influence on the suction ability which gives rise to the adjustment of the distance and the degree.

EXAMPLES

Figure 1 is a schematic side view of the apparatus in use of an embodiment of the present invention. The metal strip 1 is uncoiled, travels through the deflector roll 2, rolled by the temper mill 3, travels through the deflector roll 4, and is coiled by a tension reel (not shown).

The temper mill is a four-high mill comprising of the work rolls 5 and the back up rolls 6. The brushing rolls 7 and 8 remove the foreign objects on the surface of the work rolls and the back up rolls. The brushing rolls 7 are attached to the entry side of the work rolls 5, whereas the brushing rolls 8 are attached to the delivery side of the back up rolls 6. To transport the foreign objects, the ducts 9 which incorporate the brushing rolls 7 and 8, are attached in the neighbourhood of the work rolls 5 and the back up rolls 6, of which one end is engaged with the hood 11, of which other end is connected to the blower 10, so that the foreign objects are carried away from the rolling system. Figure 2 is a detailed schematic perspective illustration of the duct 9 in the neighbourhood of the rolls of the mill. The brushing roll 8 is incorporated in the duct 9. The hood 11 is attached to the opening of the duct 9, the area of opening of the hood 11 being changed by the link mechanism 12 driven by the hydraulic cylinder 13. The area of opening has close relationship with aforementioned suction speed. Therefore, the degree of the opening should be changed according to the diameter, and the relative position of the work rolls and back up rolls since the suction speed is influenced by these factors.

Figure 3 is a schematic illusration of the relative position of the work roll, the hood, and the brushing roll. The diameters of the work roll and the brushing roll are to be changed by the re-polishing thereof, and the position of the brushing roll relative to the work roll and the opening of the hood should be changed according to the change of the diameters of the work roll 5 to maintain the suction speed constant.

As shown in Figure 3, by the change of the radius of the work roll from R_1 to R_2 , the center of the polishing roll should be changed from point A to point B, and the degree of the opening of the hood should be changed from a to b to maintain the distance between the surface of the work roll and the tip of the hood, denoted as h, constant. This method is also applicable to the back up roll.

Figure 4 is a schematic side view of a mechanism of moving the duct. As shown in Figure 4, the brushing roll is incorporated in the moving part of the duct 9 flexicbly connected to the main part of the duct. The duct is mounted on the carrier 14 which is driven by the motor 16 on the rail 15.

Figures 5 and 6 are flow charts which automatically change the position of the brushing rolls and the opening of the duct, in mill operation, roll changing, and mill stop. Figure 5 is a flow chart showing the control logics in the series of operations from the roll changing to the starting up. Figure 6 is a flow chart showing the cotrol logic in the series of operations from the mill stop to the starting up. As is shown in Figure 5, when an operater orders the work roll changing, the brushing roll recesses to the position where the brushing roll does not interfere with the roll changing operation. The brushing roll accesses and contacts to the work roll with the signal of the finish of the roll changing , adjusting the position of the duct according

to the information of the diameter of the changed rolls. The opening of the hood is also adjusted. The brushing roll is pressed to the work roll untill the electric current of the motor for the brushing roll reaches a predetermined value. The position of the duct is also adjusted in the back up roll changing, in the changing of the work roll and back up roll, and in case of the change of the vertical position of the rolls of the mill by using shims. The same positioning method can be applied to the alteration of the diameter of the brushing roll.

Moreover, the predetermined value of the electric current is changeable according to the diameter of the brushing roll.

As shown in Figure 6, when an operater orders the mill stop, the brushing roll recedes to the position where the brushing roll does not touch the work rolls. When the mill restarts and the peripheral speed of the work roll reaches 30 mpm, the brushing roll approaches and contacts to the work roll, being pressed to the work roll untill the electric current of the motor for the brushing roll reaches a predetermined value.

Figure 7 is a schematic perspective illustration showing the assembly of the brushing roll. The shaft of the brushing roll 17 is equipped with air supply tunnel 18. The outer cylinder 19 is fixed to the shaft 17 , which is equipped with the holes 22 for flowing out of the air. The discs 20 are fixed to the outer cylinder 16, on top of which bristle 21 is imbedded. This structure is the result of the consideration of the even distribution of the density of the bristle.

Figure 8 is the enlarged view of the structure of the brushing roll shown in Figure 7.

Consideration is given to the uniform air flow to the outer surface of the bristle 21 by adopting the diameter of the holes 22 larger than the thickness of the disc 20.

ROLLING TEST EXAMPLE 1

Rolling tests are carried out to verify the validity of the scope of the present invention. The condition of the test 1 is as follows:

(i) work roll,
material; forged steel,
hardness; Hs 92.,
surface roughness; 2.0 to 2.2 μR_a
(ii) back up roll,
material; cast iron,
hardness; Hs 68.,
surface roughness; 0.08 to 0.1 μR_a
(iii) brushing roll,
for work roll,
material; nylon,
diameter; 170 mm,
number of revolution; 350 rpm,
for back up roll,
material; nylon,
diameter; 260 mm,
number of revolution; 400 rpm,
abrasive grain; incorporated,
(iv) suction speed,
4, 6, 8, 10, m/sec.,
(v) rolled material,
as annealed cold reduced steel strip,
(vi) rolling method,
dry tempering.

Table 1 reports the result of the comparison between the conventional method and the method of the present invention. As is shown in Table 1, the substantial rejection is found in the finished product irrespective of the suction speed in case of the conventional method , the work roll brushing, whereas the rejection ratio is below 4% with suction speed of more than 5 m/sec. and the rejection ratio is zero with suction speed of more than 10 m/sec in case of the present invention wherein the back up roll, or the work roll and back up roll is brushed.

Figure 9 is a graph showing the relationship between the suction speed and the dust recovery ratio. The abscissa denotes the suction speed and the ordinate denotes the dust recovery ratio. As shown in

Figure 9, the dust recovery ratio of more than 80% is attained with the suction speed of more than 5 m/sec.

Table 1

	WR	WR + BUR	BUR
Sucking Speed (m/sec.)	Rejection Ratio (%)		
4	10	5	7
6	6	2	4
8	4	0	2
10	3	0	0
WR ; work roll, BUR ; back up roll			

ROLLING TEST EXAMPLE 2

The condition of the test 2 is as follows:
(i) work roll,
material; forged steel,
hardness; Hs 92.,
surface roughness; 2.0 to 2.2 μR_a
(ii) back up roll,
material; cast iron,
hardness; Hs 68,
surface roughness; 0.08 to 0.1 μR_a
(iii) brushing roll,
for work roll,
diameter; 170 mm,
number of revolution; 350 rpm,
for back up roll,
diameter; 260 mm,
number of revolution; 400 rpm,
(iv) suction speed,
10 m/sec.,
(v) rolled material,
as annealed cold reduced steel strip,
(vi) rolling method,
dry tempering.

Table 2 reports the test results of the temper rolling with various condition of the bristle and the abrasive grain. As shown in Table 2, in the cases of comparison wherein the rolling condition is out of the scope of the invention, rejections are reported as for the quality of the finished products, whereas in the cases of the present invention, no rejections are reported. The rejections are reported in the condition of the diameters of the bristle in case of the comparison example 7 and 8, the density of the bristle in 9, the grain size of the abrasive grain of the work roll in 10, the diameter, the density of the bristle of the work roll, and the grain size of the abrasive grain of the work roll in 11, the material of the bristle, the diameter, and the grain size of the abrasive grain of the work roll in 12.

Table 2

		Brashing Condition					Rejection Ratio (%)
		Material	Dia.of Bristle (mm)	Density of Bristle at WR (%)	Grain Size of Powder at WR (#)	Grain Size of Powder at BUR (#)	
Examples of Invention	1	Nylon	0.3	85	1000	500	0
	2	Nylon	0.3	60	1000	500	0
	3	Nylon	0.5	85	without	500	0
	4	Nylon	0.5	60	without	500	0
	5	Nylon	0.8	80	without	1000	0
	6	Nylon	0.8	70	without	1000	0
Examples of Comparison	7	Nylon	0.9	85	without	500	3
	8	Nylon	0.9	80	without	1000	2
	9	Nylon	0.5	50	without	500	1.5
	10	Nylon	0.3	60	500	500	1
	11	Nylon	0.15	50	500	500	3
	12	Stainless steel	0.15	70	without	without	10
WR ; work roll, BUR ; back up roll,							

ROLLING TEST EXAMPLE 3

The condition of the test 3 is as follows:

(i) work roll,
material; forged steel,
hardness; Hs 92.,
surface roughness; 2.0 to 2.2 μR_a

(ii) back up roll,
material; cast iron,
hardness; Hs 68.,
surface roughness; 0.08 to 0.1 μR_a

(iii) brushing roll,
for work roll,
material of bristle; nylon,
diameter of bristle; 0.6mm,
length of bristle; 45mm,
material of abrasive grain; alumina,
grain size of abrasive grain; #600,
volume ratio of abrasive grain; 20% in volume of the brush,
diameter; 170 mm,
number of revolution; 350 rpm,
suction speed; 8.5 m/sec.,
for back up roll,
material of bristle; nylon 60 % + polypropyrene 40 %,
diameter of bristle; 0.5mm,

length of bristle; 50mm,
material of abrasive grain; alumina,
grain size of abrasive grain; #800,
volume ratio of abrasive grain; 10% in volume of the brush,
diameter; 260 mm,
number of revolution; 400 rpm,
suction speed; 8.0 m/sec.,
(IV) rolled material,
as annealed cold reduced steel strip,
(V) rolling method,
dry tempering.

Figures 10 and 11 are graphs showing the relationship between the diameter of the bristle and the number or the volume of the iron particle per unit area of the surface of the roll of the mill.

The abscissa denotes the diameter of the bristle and the ordinate denotes the number or the volume of the iron particles per unit area of the surface of the roll of the mill. The triangular mark denotes the data of the present invention, and the circular mark denotes the data wherein the rolling is done without applying the abrasive grain to the brush. As is shown in Figures 10 and 11, the diameter of the bristle is preferrable in the range of from 0.15 to 1.0mm, more preferable in the range of from 0.2 to 0.8mm. The application of the abrasive grain to the brush is effective to remove theforeign objects. However, when the grain size of the abrasive grain is above #300, the polishing effect to the roll of the mill is too much, which results in the generation of scratch mark on the surface of the roll of the mill. When the grain size is below #1200, the brushing effect is not sufficient.

Figure 12 is a graph showing the relationship between the suction speed and the quantity of dust in the air at the back up roll. As shown in Figure 12, the dust per unit volume of air ; $2 \times 10^{-2} mg/m^3$ is about the same with that of the ambient atmospheric air, with the suction speed of at least 8 m/sec.

The length of the bristle influences on the rigidity of the bristle and the brushing effect. When the length is too large, the bristle loses the rigidity which causes the worsening of the brushing effect, whereas the appropriate recovery after brushing is lost which also causes the worsening of the brushing effect, when the length is too short. Accordingly, the length is determined to be from 15 to 60 mm.

The present invention is applicable to the in-line rolling for heat treating lines, plating lines, and multi-rolled mills other than four-high mills.

Reference signs in the claims are intended for better understanding and shall not limit the scope.

Claims

1. A cold rolling method of strip(1), characterized by comprising the steps of;
contacting at least one brushing roll(8) to a pair of back up rolls(6) with the directions of the rotation thereof being the same with that of said pair of back up rolls, and
sucking the air into ducts(9), which are equipped with access and recess mechanisms, in the neighbourhood of said brushing rolls, wherein the speed of the suction of the air surrounding said ducts is at least 5 m/sec.

2. A cold rolling method of strip of claim 1, characterized in that the speed of the suction of the air surrounding said ducts is at least 8 m/sec.

3. A cold rolling method of strip of claim 1, characterized in that a plurarity of said brushing rolls (7), (8) are contacted to a pair of work rolls(5) and a pair of back up rolls.

4. A cold rolling method of strip of claim 1, characterized in that the direction of the rotation of the brushing roll is adverse to that of the back up rolls.

5. A cold rolling method of strip of claim 2, characterized in that the direction of the rotation of the brushing roll is adverse to that of the back up rolls.

6. A cold rolling method of strip of claim 3, characterized in that the direction of the rotation of the brushing rolls is adverse to those of the work rolls and the back up rolls.

7. A cold rolling method of strip(1), characterized by comprisingthe steps of:
contacting a plurarity of brushing rolls(7),(8) to a pair of work rolls (5) and a pair of back up rolls (6) with the directions of the rotation thereof adverse to those of said work rolls and back up rolls, and
sucking the air into ducts(9), which are equipped with access and recess mechanisms, in the neighbourhood of said brushing rolls, wherein the diameter of the bristle of said brushing rolls for said work rolls is from 0.2to 0.8mm, the surface of said brushing roll, and the grain size of abrasive grains incorporated in

the brush of said brushing rolls is below #1000.

8. A cold rolling method of strip(1), characterized by comprisingthe steps of:

contacting a plurarity of brushing rolls(7),(8) to a pair of work rolls (5) and a pair of back up rolls (6) with the directions of the rotation thereof adverse to those of said work rolls and back up rolls, and

sucking the air into ducts(9), which are equipped with access and recess mechanisms, in the neighbourhood of said brushing rolls, wherein the diameter ofthe bristle of said brushing rolls for said back up rolls being from 0.2 to 0.8 mm, and the grain size of abrasive grains incorporated in the brush of said brushing rolls being from #500 to #1000.

9. A cold rolling method of strip(1), characterized by comprisingth steps of:

contacting a plurarity of brushing rolls(7),(8) to a pair of work rolls (5) and a pair of back up rolls (6) with the directions of the rotation thereof adverse to those of said work rolls and backup rolls, and

sucking the air into ducts(9), which are equipped with access and recess mechanisms, in the neighbourhood of said brushing rolls, wherein the diameter of the bristle of said brushing rolls for said work roll and back up rollsisfrom 0.15 to 1.0 mm, the length of said bristle being from 15 to 60 mm , the material thereof being selected from a groupe of nylon, polypropyrene, and the mixture thereof, the material of the abrasive grain being one or more selectd from a groupe of alumina, titania, and silicate, the grain size thereof being from #300 to #1200, the volume percent thereof with respect to the volume of the brush of the brushing roll being from 5 to 30 % in volume.

FIG. 1

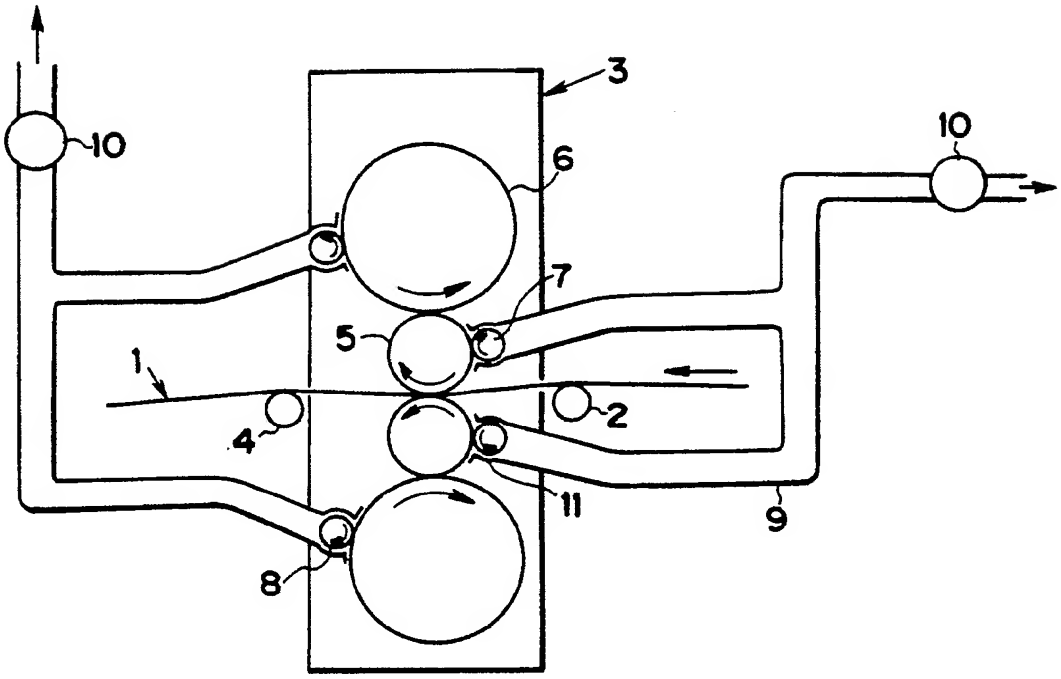


FIG. 2

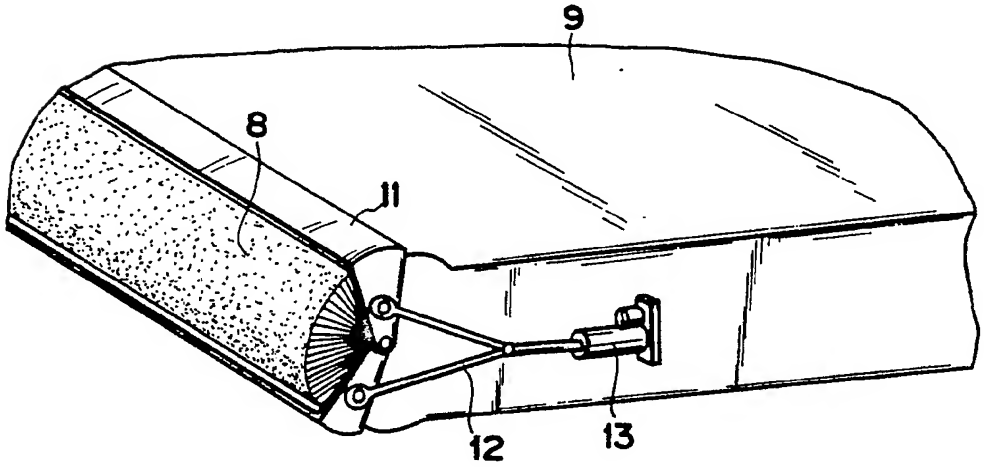


FIG. 3

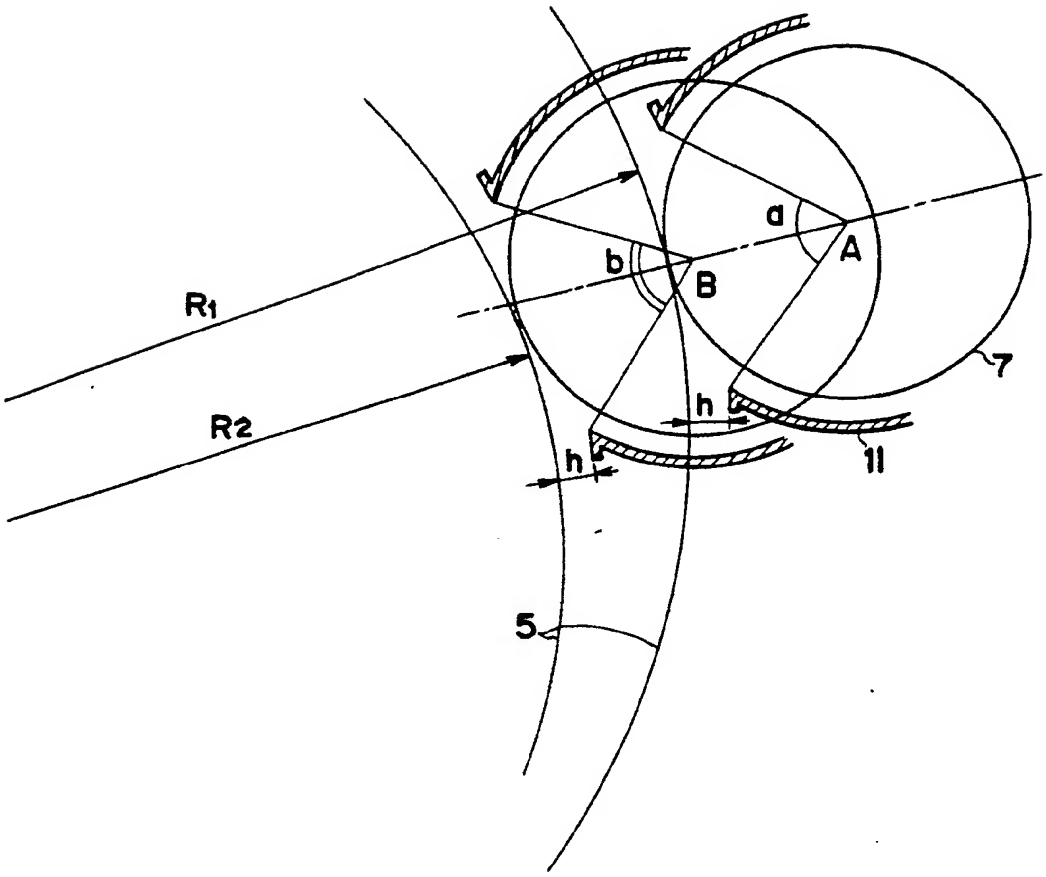


FIG. 4

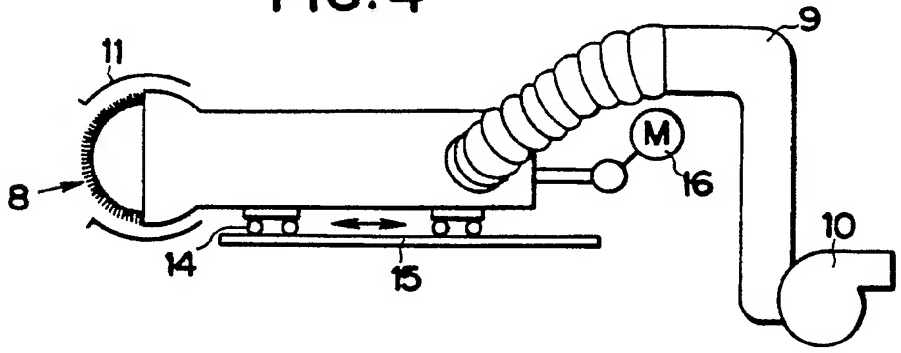


FIG. 5

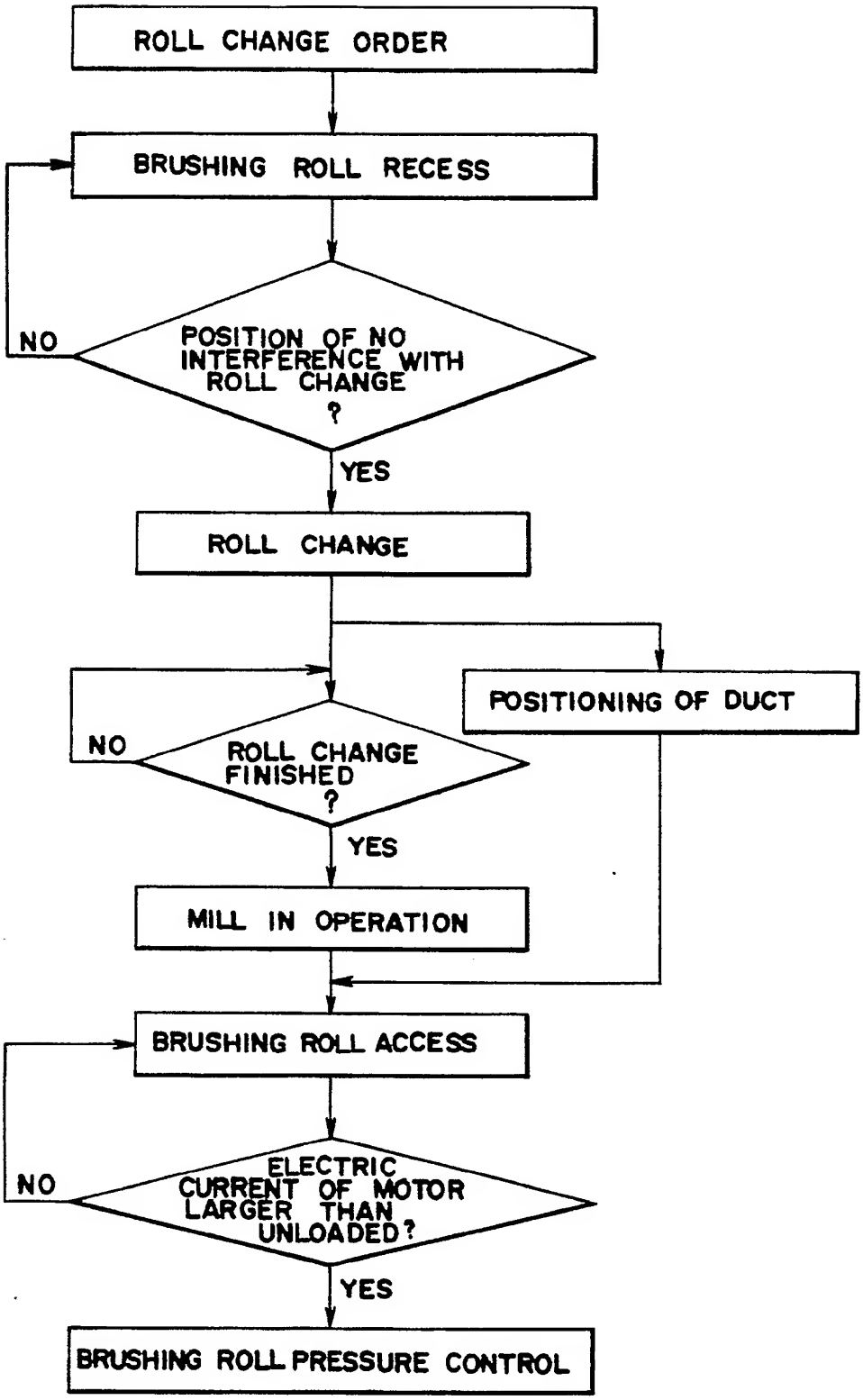

ROLL CHANGE ORDER
BRUSHING ROLL RECESS
NO
POSITION OF NO INTERFERENCE WITH ROLL CHANGE ?
YES
ROLL CHANGE
POSITIONING OF DUCT
NO
ROLL CHANGE FINISHED ?
YES
MILL IN OPERATION
BRUSHING ROLL ACCESS
NO
ELECTRIC CURRENT OF MOTOR LARGER THAN UNLOADED?
YES
BRUSHING ROLL PRESSURE CONTROL

FIG. 6

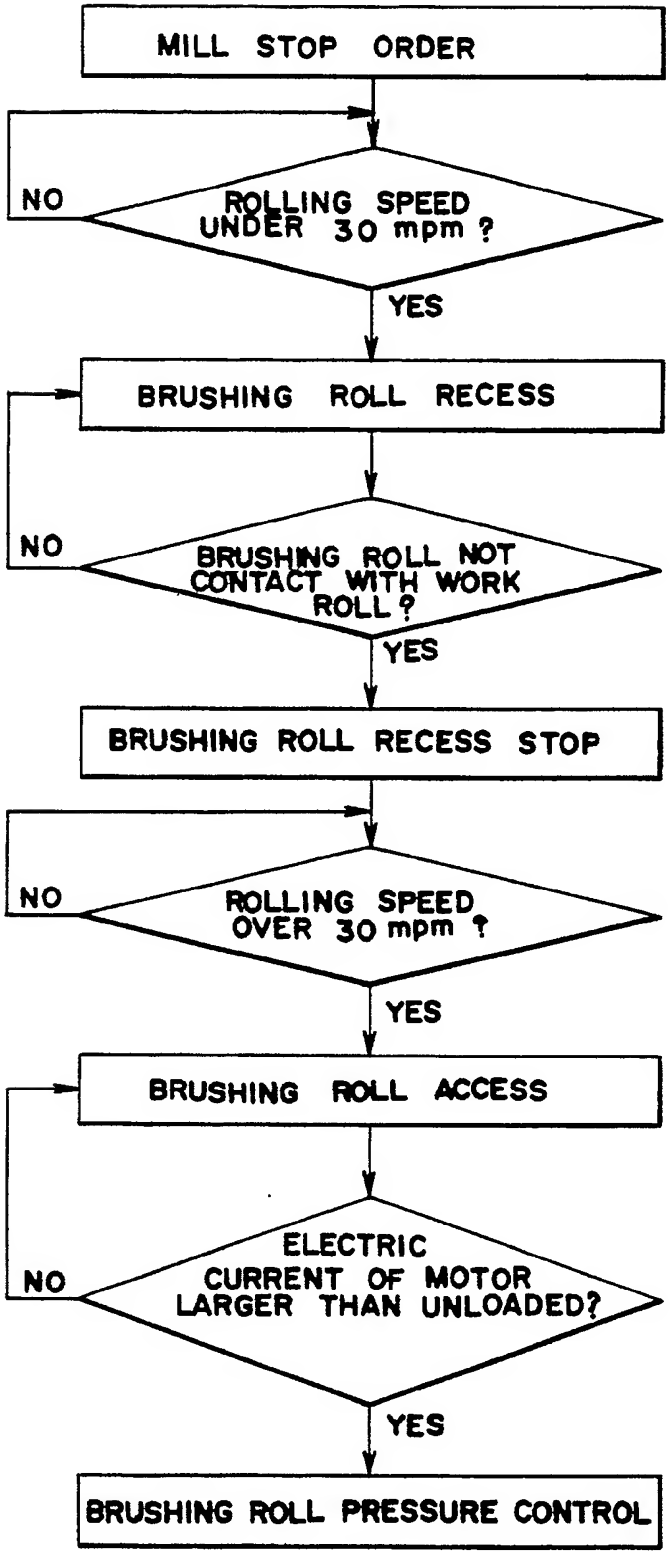

MILL STOP ORDER
NO
ROLLING SPEED UNDER 30 mpm ?
YES
BRUSHING ROLL RECESS
NO
BRUSHING ROLL NOT CONTACT WITH WORK ROLL ?
YES
BRUSHING ROLL RECESS STOP
NO
ROLLING SPEED OVER 30 mpm ?
YES
BRUSHING ROLL ACCESS
NO
ELECTRIC CURRENT OF MOTOR LARGER THAN UNLOADED?
YES
BRUSHING ROLL PRESSURE CONTROL

FIG. 7

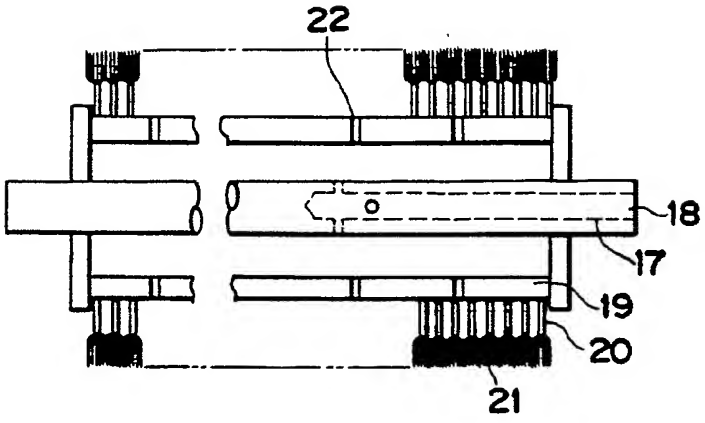


FIG. 8

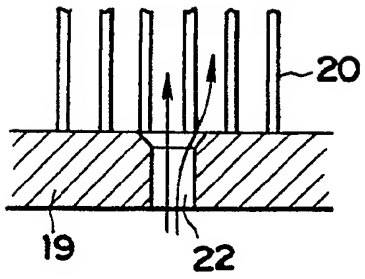


FIG. 9

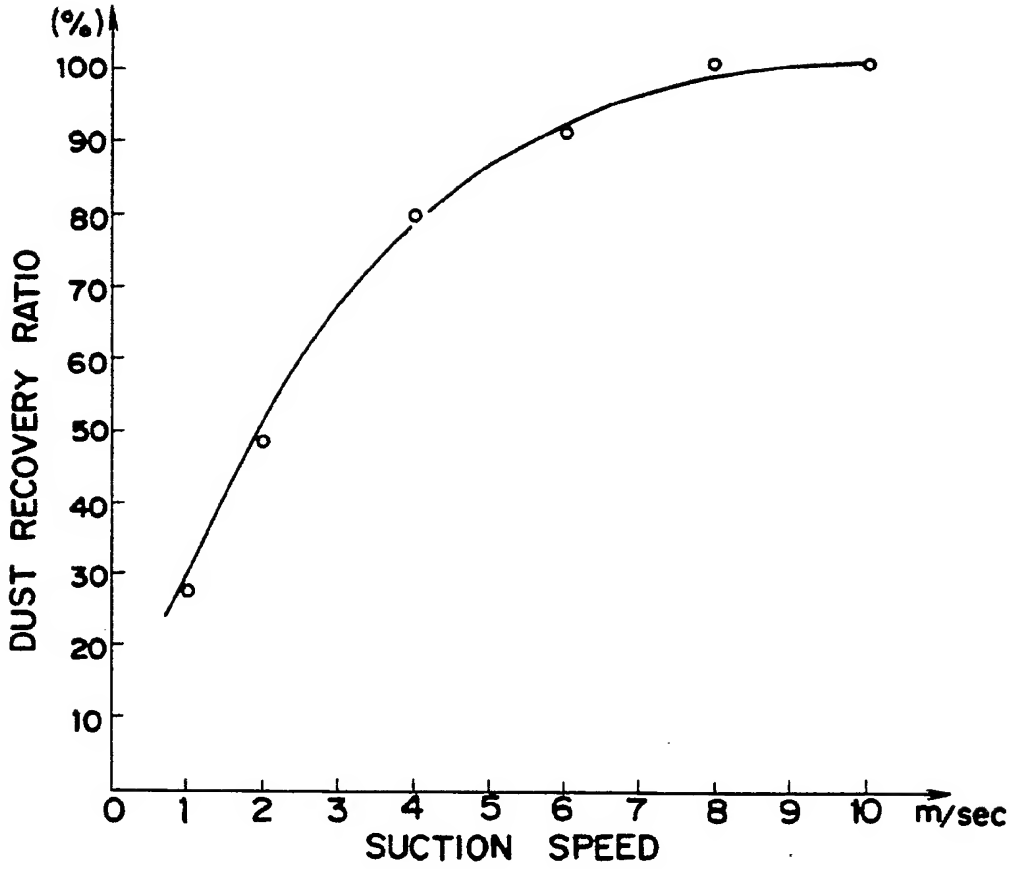

(%)
100
90
80
70
60
50
40
30
20
10
DUST RECOVERY RATIO
0
1
2
3
4
5
6
7
8
9
10
m/sec
SUCTION SPEED

FIG. 10

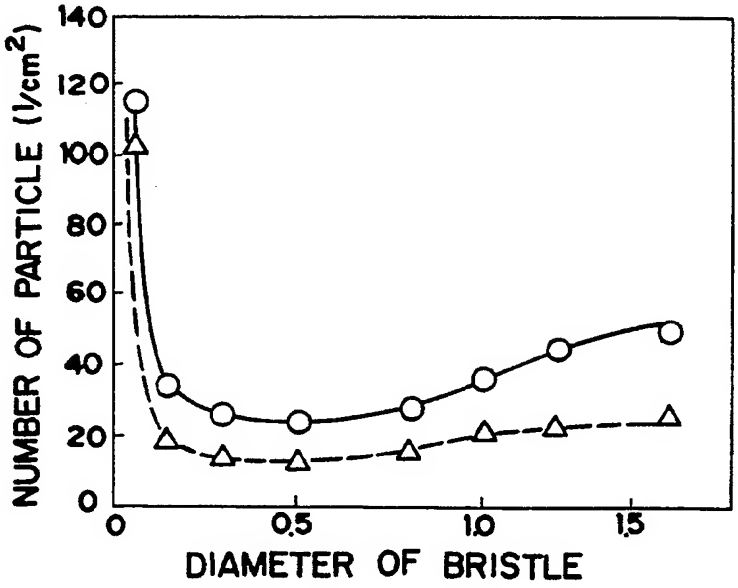

140
120
100
80
60
40
20
0
NUMBER OF PARTICLE (1/cm²)
0
0.5
1.0
1.5
DIAMETER OF BRISTLE

FIG. 11

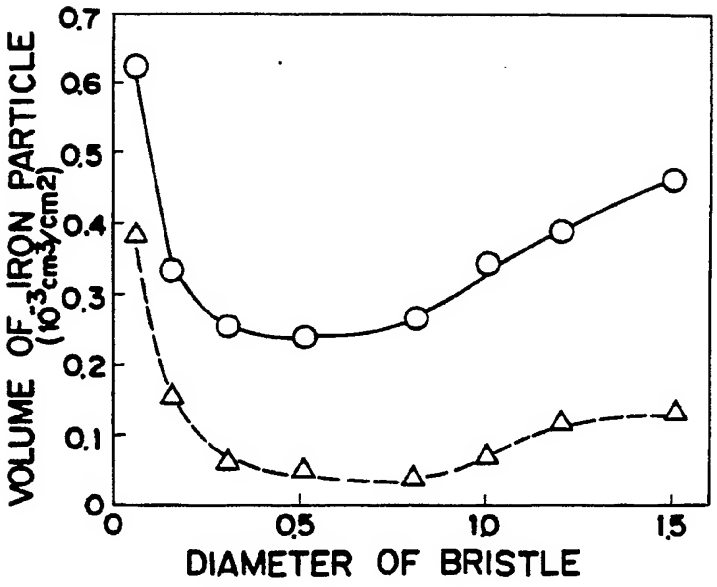
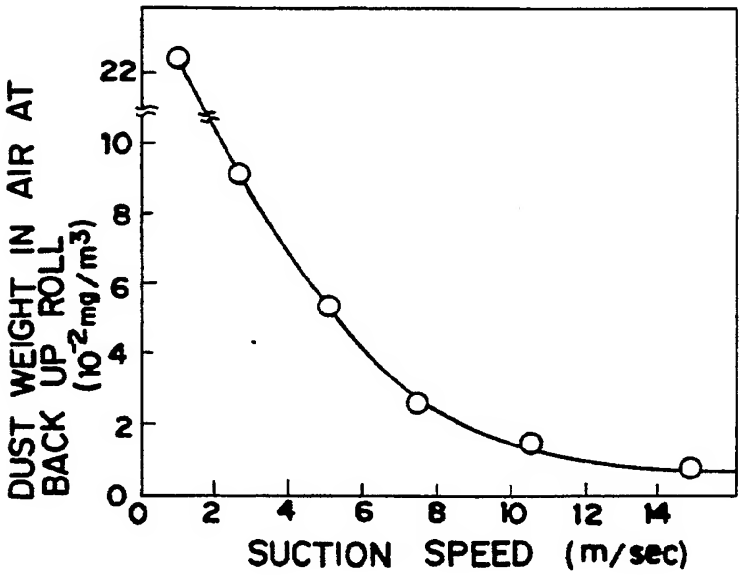

VOLUME OF IRON PARTICLE
(10^{-3}cm^3/cm^2)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1.0
1.5
DIAMETER OF BRISTLE

FIG. 12


DUST WEIGHT IN AIR AT BACK UP ROLL
(10^{-2}mg/m^3)
22
10
8
6
4
2
0
0
2
4
6
8
10
12
14
SUCTION SPEED (m/sec)